



Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at <http://about.jstor.org/participate-jstor/individuals/early-journal-content>.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

where a few species indicating a fauna of Utica age have been collected. In general the Trenton beds are followed immediately by strata containing a Silurian (Upper Silurian) fauna of Niagara or Wenlock age.

STUART WELLER.

The Glacial Palagonite-Formation of Iceland. By HELGI PJETURSSON, Cand. Mag. Copenhagen. The Scottish Geographical Magazine, May 1900, Vol. XVI, No. 5.

This appears to be a very important contribution to the history of Pleistocene glaciation. It opens up a new and very promising field, whose data are peculiar because of their association with volcanic phenomena. The author presents in much detail, and with apparent care and discrimination, evidence of glacial formations antedating the so-called "preglacial" lava flows, as well as others interstratified with the lava flows. After twenty-two pages devoted to description of details, illustrated by figures, the author draws the following important conclusions:

I shall not be surprised if this account of the occurrence of glacial deposits and striated rock surfaces in connection with the "palagonite-formation" of Iceland is received with incredulity. For myself, I could hardly believe the evidence when I first encountered it, and tried to explain it in every possible way other than by glacial action. But the glacial origin of the "breccias" could not be gainsaid. Not only did they present a characteristically morainic aspect, but they yielded numerous well striated stones, and in places were found to be resting upon grooved and striated rock surfaces. If the observations I have here recorded be accepted as fairly trustworthy, we cannot avoid the conclusion that glacial deposits, hitherto unrecognized as such, are largely developed in Iceland, or at all events in that part of the island which I have critically examined and referred to in these pages.

As I have had only a glimpse, as it were, into this very promising field of glacial research, I shall not attempt to deal with the glacial succession in Iceland. That must be left for future investigations to determine. Nevertheless there are several conclusions which seem to me obvious enough. Of these the most important, in my opinion, is that which has reference to successive glaciations. The facts advanced show that Iceland has experienced more than one glaciation before the ejection of the doleritic lavas and their subsequent smoothing and grooving by ice. How many separate glaciations the morainic breccias bear witness to is uncertain. But the repeated occurrence of four separate sheets or beds of morainic breccia seems to render it not improbable that there have been just as many separate glaciations during the

accumulation of the so-called palagonite formation. Even if we discard the evidence furnished by the lowest breccias (in which, it will be remembered, that notwithstanding their morainic aspect, no striated stones occurred), we have still the overwhelming evidence of glaciation supplied by the higher morainic breccias. But whether these indurated ground moraines represent three, four, or more glaciations, one or other of them must represent the epoch of maximum glaciation in Europe. The glaciation which left the older system of markings on the dolerite of Stangasfjall is, of course, of later date and may possibly represent the Mecklenburgian stage (Geikie) of northern Europe, and the first postglacial stage of glaciation of the Alps (Penck). It seems more than probable that a change of climate, corresponding to that which in the Alps depressed the snow line about 3000 feet, would bring about the total glaciation of Iceland. Indeed, a much less important change in the climatic conditions would suffice to do this. It is therefore quite possible that the younger system of striae marking the surfaces of the dolerites may be contemporaneous with that readvance of cold conditions which produced the local glaciers of the "Lower Turbarian stage" of Scotland, and those of the "Second postglacial stage" in the Alps.

[The second striated horizon in the moraine of Sudurnes (if it be not a striated pavement) may possibly indicate a third "post-doleritic" glaciation, but until additional evidence be forthcoming, this isolated observation must be left out of consideration.]

So far as I know, all that has been written on the glacial period in Iceland refers to the minor glaciations which supervened after the ejection of the doleritic streams of lava. I say minor glaciations, even although the country appears during those stages to have been totally ice-covered. But the mass of the "palagonite-moraines" is so very much greater than that of the loose accumulations of the later glaciations, that we may reasonably infer that the former are products of much greater ice-sheets. Moreover, the conditions of erosion and accumulation during successive glaciations seem to have differed at the same localities. Further, when we remember that the whole region throughout which the palagonite-formation occurs, has been extensively fractured and consequently has experienced many subsidences—and when we reflect that all these important deformations of the land surface took place subsequent to the accumulation of the uppermost morainic breccias, we are led to suspect that the area over which the older glaciations prevailed may have considerably exceeded that which now exists. Probably conclusive evidence on this point may be obtained by studying the directions of the oldest glacial striae all over the country, and more especially in the north.

It would probably also be of great interest to determine the relations of the Pliocene shell-beds near Húsavík, North Iceland, to the "tuff- and breccia formation." As I have obtained a grant from the Carlsberg Fund,

Copenhagen, to enable me to continue these investigations, I hope to do so on the lines here indicated.

About 5500 square miles of the total area of Iceland are at present covered with glaciers. The country, therefore, would seem to be in a state of glaciation comparable to that obtaining in Scotland during the fourth glacial epoch as defined by Professor Geikie. Now, if Iceland were to be once more totally glaciated, should we term that final ice-invasion a separate stage of glaciation; or merely an oscillation of the existing glaciers? Would the present inhabited condition of Iceland be considered an interglacial epoch, or merely a stage of temporary glacial retreat?

Such considerations must be kept in view when we are discussing whether the old ground moraines described in this paper have been laid down by an oscillating ice-sheet or during separate glacial epochs.

In Búrfell two bottom-moraines are separated by 150 to 200 feet of basalt, on the striated surface of which the upper moraine reposes. Possibly, however, that basalt does not mark the lowest interglacial horizon.

To the next succeeding interglacial horizon probably belong the conglomerates of Stangarfjall, Bringa, and Hagafjall, which are supposed to be of fluvial origin. Perhaps also the columnar dolerite of Stangarfjall should be included here. The existence of those conglomerates at such heights and so far inland suggests at least a very considerable oscillation of the ice-sheet. Moreover, we must not forget that the conglomerates in question are buried underneath masses of various volcanic products. [While some of the old gravel beds may well represent old river channels, in other places, as in Hagafjall and Bringa, they had more the character of lacustrine deltas or *cônes de déjection*.]

The next interval between two glaciations is that marked by the so-called "preglacial dolerites" which henceforward cannot claim to be more than interglacial. "At the time these preglacial lava beds were laid down, the country had pretty much the same essential contours that it has at present."¹ But when the uppermost of the "palagonite-moraines" (as in Berghylsfjall and Hagafjall) were laid down, the relief of the country, as we have seen, differed greatly from that which now obtains. In the interval of time that separates these morainic breccias from the eruption of the later lavas, the most radical changes in the contours of the country had been effected, chiefly perhaps by subsidence. The southern lowland of Iceland cannot date farther back than this interglacial epoch.

It is not improbable, indeed, that the essential contour lines or surface features of the whole island, so far as these are older than the later outflows of dolerite, came into existence during this interglacial epoch. We cannot tell at what particular stage the later dolerites were erupted, but we know

¹ Thoroddsen, Explorations etc., p. 35.

that the changes of relief which were effected during the interglacial stage in question were very much greater than those which have taken place since the outflow of the doleritic lavas. And yet these lavas have been glaciated more than once, and we do not know how long they had to wait for their first glaciation.

We seem therefore justified in coming to the conclusion that the two glaciations in question have not been the result of comparatively insignificant oscillations of an ice-sheet, but were really separated by a protracted period. The very occurrence indeed of the interglacial streams of lava over such great areas suffices to show how extensively the ice-sheet melted away. It seems to me highly probable that *all* the so-called "preglacial" lavas are in reality interglacial.

Furthermore, the evidence leads to the inference that the time which has elapsed since the last ice-sheet disappeared from the southern lowland of Iceland is very short as compared to the interglacial epoch that intervened between the first of the glaciations experienced by the dolerites and that next preceding it.

Whether the supposed marine deposit which underlies the glaciated lava on Tungufljót dates back to the closing stages of the interglacial epoch just mentioned, or whether it ought rather to be ascribed to an interval separating the two glaciations which are represented by the two systems of striae upon the surfaces of the later dolerites, future investigations must be left to determine.

No doubt many additional conclusions are suggested by the observations recorded in this paper, but I do not care to consider these at present. As already stated, the chief object of this paper is to point out that there exists in Iceland much hitherto unsuspected evidence of former glacial action. I am indeed sanguine enough to think it not improbable that the records of the glacial period have been more fully preserved here than elsewhere. For it is obvious that the conditions for the protection and preservation of glacial deposits have been with us somewhat exceptional. While in other lands, free from volcanic activity, each succeeding ice-sheet has partly destroyed and partly covered up the deposits of its predecessor, in Iceland the moraines have been greatly sheltered by the products of volcanic eruptions which overlie them. Moreover, crustal movements have contributed directly toward the same end by placing the old moraines beyond the reach, as it were, of succeeding glacial invasions. Not improbably, too, some rocks of the "tuff- and breccia-formation" may be due to the direct interaction of volcanic and glacial forces.

To this is added the discussion of some points of a more special and local nature. It is gratifying to learn that the investigation is likely to be continued.

T. C. C.